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THE EFFECT OF A PREVENTIVE MAINTENANCE PROGRAM ON THE FAILURE RATE OF FIXED MECHANICAL EQUIPMENT

by

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Abstract

THE EFFECT OF A PREVENTIVE MAINTENANCE PROGRAM ON THE FAILURE RATE OF FIXED MECHANICAL EQUIPMENT

Edward St. Pierre

The premature failure rate of certain types of fixed mechanical equipment, such as air handling units and pumps, in the Sheboygan Area School District was unacceptably high. This contributed to inflated maintenance and repair costs. The researcher developed, implemented and evaluated the effect of a preventive maintenance (PM) program on the failure rate of such equipment.

A quasiexperimental, nonequivalent control group research design was used in which the independent variable (IV) was PM and the dependent variable (DV) was the failure rate of fixed mechanical equipment. During the experimental period, November 25, 1985, to February 25, 1986, PM procedures were applied to the fixed mechanical equipment in four school buildings. Four other buildings, selected as controls, did not receive PM. The number of failures of equipment included in the PM program was determined for each of the test and control buildings. Cost data was also main-

tained for both PM work and all other repair work. Pretest failures were obtained from an ex post facto examination of maintenance records for the period from November 26, 1984, to February 26, 1985. This time period was used because it corresponded to the test period, and operating demands on the equipment were similar. Failure rates were calculated as the percentage of equipment included in the program which failed, compared to the total amount of equipment included in the program.

Although the quantitative figures regarding the effects of the PM program on the failure rate of fixed mechanical equipment did not clearly show the benefits of such a system, the observations of the researcher and the other program participants tended to support the premise that a PM program was a necessary and valuable part of a well managed school maintenance operation. The researcher, therefore, recommended that the PM program be incorporated with the routine responsibilities of the department of buildings and grounds.

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Purpose and Title of Project

Purpose

The premature failure rate of certain types of fixed mechanical equipment, such as air handling units and pumps, in the Sheboygan Area School District (SASD) was unacceptably high. This contributed to inflated maintenance and repair costs and limited the ability of district personnel to plan for and control these costs. Additionally, planned work schedules of maintenance department employees frequently had to be interrupted to make emergency repairs on failed equipment. The researcher developed, implemented and evaluated the effect of a preventive maintenance (PM) program on the failure rate of such equipment.

Title

The title of the project was "The Effect of a Preventive Maintenance Program on the Failure Rate of Fixed Mechanical Equipment."

Problem Statement

Statement of the Problem

The Sheboygan Area School District contained a total of over 382 pieces of fixed mechanical equipment distributed among twenty separate buildings. The researcher defined fixed mechanical equipment as any unit permanently mounted or attached to a building and the function of which was to perform mechanical work. This included heating, ventilating and air conditioning equipment, electric motors, pumps and air compressors. It did not include components of the building structure, boilers, plumbing fixtures or movable machinery.

During the period from July 1, 1984, to June 30, 1985, the SASD experienced 206 failures of fixed mechanical equipment. Based upon an examination of the District's maintenance records, the researcher estimated that thirty-five of these breakdowns were avoidable through properly designed and implemented preventive maintenance procedures. The avoidable failures cost the district 161 manhours of maintenance department labor and $2,678.74 for repair materials and contracted services. (See Appendix A for examples of typical failures.)

Background Information

The SASD was comprised of twenty separate buildings containing a total of 1,670,828 square feet of space on property totaling 316.76 acres. Included were two high schools, three middle schools, twelve elementary schools, one administration building, one school leased to others and one unoccupied school building.

The oldest of the schools was Longfellow Elementary, built in 1890, and the newest was Pigeon River Elementary, built in 1981. The two high schools, which contained 30 percent of the district's total floor space, were completed in 1960 and 1961. Most of the buildings had additions constructed, or underwent renovation, at some point in their history.

Because the buildings were constructed over a time span of ninety-five years, they showed a great diversity of architectural styles, engineering concepts, and technological states. Most of these buildings predated the energy crisis of the seventies and were, therefore, not designed for efficient energy use. However, as Basil Castaldi stated in Educational Facilities Planning, Modernization, and Management, "with a plentiful supply of inexpensive energy, this design posed no significant problems."[1] In particular, those buildings constructed during the 1960's had excessively large, complex and wasteful heating and ventilating systems. For example, Horace Mann Middle School with 174,517 square feet, completed in 1969, contained seventeen heating and ventilating units with motors exceeding one-horsepower. In comparison, Urban Middle School, with 146,856 square feet constructed in 1936 and 10,000 square feet added in 1982, contained only eight such units. Except for routine lubrication of this equipment by the buildings' custodial staffs, no maintenance was generally performed until a problem was encountered. During the period from July 1, 1984, through June 30, 1985, 206 equipment failures occurred. Repairs cost the SASD 1,027.5 manhours of maintenance department labor and $11,064.56 for materials and contracted services.

The diversity of the buildings and the equipment they contained compounded the district's maintenance problems. Numerous manufacturers were represented, and some, such as Domestic Pump, Incorporated, were no longer in business. Much of the equipment was obsolete and repair parts were, therefore, unavailable. This made replacement, rather than repair, a frequent necessity. In addition, as time passed, maintenance and repair manuals were often lost or misplaced. Such loss made the establishment of regular maintenance procedures difficult, and neglect was common.

Need for the Project

The SASD Board of Education, during budget hearings in 1985, emphasized the need to reduce waste and curtail rising costs. The maintenance budget was $836,021.79 for fiscal 1984-1985 and $875,294.17 for fiscal 1985-1986.[2] Adjusted for an annual inflation rate of 3.6 percent, the 1985-1986 budget represented a real increase of only 1.1 percent.[3] It was essential that a method be developed to control such costs. The PM program, through the application of routine maintenance procedures recommended by the equipment manufacturers to prolong equipment life, reduced the failure rate of fixed mechanical equipment in the SASD, and this reduced maintenance costs and allowed better planning and control.

The reduced equipment failure rate also reduced the number of emergency or unscheduled repairs made by the District's maintenance personnel. Work schedules of these personnel could be better planned which, in turn, was necessary for implementation of the PM program. In addition, downtime, the time that equipment was shut off for maintenance or repair, was generally unscheduled prior to implementation of the PM program and resulted from unplanned breakdowns. Such failures caused numerous complaints about the performance of the maintenance department. The PM program reduced unscheduled downtime, and, although records were not available, the number of complaints appeared to decrease.

Project Location and Duration

Location

The preventive maintenance program was implemented in the Sheboygan Area School District. The SASD was a complex of twenty buildings containing 1,670,828 square feet. Geographically the district occupied an area of sixty square miles in eastern Sheboygan County, Wisconsin, and a portion of Manitowoc County north of Sheboygan.

Duration

Development of the PM program began in August, 1985. The project ended in April, 1986.

Objectives

Developmental Objective #1

By October 4, 1985, the researcher determined the annual resources in manpower and material which would be allocated to the preventive maintenance program.

1. Implementation Activities
    a. Maintenance records for the preceeding year were reviewed to determine which equipment

failures might have been avoided through preventive maintenance procedures.

b. Total manhours and material costs for preventable equipment failures were calculated.

c. Manpower and material resources to be devoted to the preventive maintenance program were derived from the totals for preventable equipment failures.

d. Lists of equipment to be included in the PM program, consistent with the resources available, were derived.

2. Evidence of Completion - A budget of manhours and material resources was available for the administration of the preventive maintenance program.

Developmental Objective #2

By November 22, 1985, the researcher had trained the maintenance department staff in the procedures which would be used in the PM program.

1. Implementation Activities

a. An outline of PM goals, objectives and procedures was written.

b. A training session was held with the maintenance department staff to review PM goals, objectives and procedures.

2. Evidence of Completion - An agenda and PM program outline was available for the staff training session. (Appendix B)

Developmental Objective #3

By November 25, 1985, the researcher completed, and was ready to implement, the preventive maintenance program.

1. Implementation Activities
    a. An inventory of all equipment to be included in the plan was performed.
    b. In so far as possible, manufacturers' service manuals were obtained for all equipment.
    c. Based upon manufacturers' recommendations, service procedures and intervals were established for each piece of equipment.
    d. A master service form was designed and completed for each piece of equipment.
    e. Service files, containing the master service forms were established for each piece of equipment.
    f. A calendar file was developed to schedule maintenance according to manufacturers' recommended service intervals.
2. Evidence of Completion - A service file containing a master service form for each piece of equipment,

and a calendar file for scheduling maintenance according to manufacturers' recommended intervals, was available for implementation of the preventive maintenance program.

Evaluation Objective #1:

The rate of premature failure of fixed mechanical equipment in the Sheboygan Area School District was reduced by 15 percent, as based upon a comparison of maintenance records prior to and following implementation of the preventive maintenance program.

Evaluation Objective #2:

The cost for maintenance materials in the Sheboygan Area School District was reduced by 20 percent, as based upon a comparison of maintenance costs prior to and following implementation of the preventive maintenance program.

Evaluation Methodology

Target Population and Sampling Methodology Used

The target population was the fixed mechanical equipment of the SASD which was distributed among twenty separate buildings. Fixed mechanical equipment was defined as any unit permanently mounted or attached to a building and the function of which was to perform mechanical work. Such equipment included heating, ventilating and air conditioning equipment, electric motors, pumps and air compressors but did not include components of the building structure, boilers, plumbing fixtures or movable machinery.

A complete census or inventory of all equipment was conducted for each builing. In so far as possible, this was done through an examination of the records, such as building plans, of the SASD department of buildings and grounds. When necessary, this process was supplemented by field examination of actual equipment. The researcher carried out this step with assistance from the supervisor of maintenance, the office clerical staff and the building head custodians.

The researcher recognized at the start of the project that it was not possible to include all of the district's equipment in the PM program. Due to limitations on the available resources in manpower and material, the researcher decided that only equipment critical to the operation of the SASD, such as emergency power generators, or with potentially high replacement or repair costs, such as electric motors exceeding one-horsepower, would be included in the program. The researcher selected equipment which fit into these two categories from the complete inventories. Evaluation criteria included actual repair and replacement costs, as determined from an examination of SASD records. (See Appendix C for a complete list of equipment included in the PM Program.)

Research Design and Procedures

The researcher selected a quasiexperimental, nonequivalent control group design, in which the control and test groups were chosen for approximate equivalency by the researcher.[4] In this design the independent variable (IV) was preventive maintenance, and the dependent variable (DV) was the failure rate of fixed mechanical equipment.

The researcher limited the study to eight buildings because this number allowed a representative selection of sizes, ages and mechanical complexity and also permitted the formation of two approximately equivalent test and control groups. (See Appendix D for a comparison of the test and control groups.)

During the experimental period, November 25, 1985, to February 25, 1986, PM procedures were applied to the fixed mechanical equipment in four buildings. These were South High School, Urban Middle School and Madison and Washington Elementary Schools. Four other buildings, North High School, Farnsworth Middle School and Grant and Longfellow

Elementary Schools, selected as controls, did not receive any preventive maintenance. The number of failures of equipment included in the PM program was determined for each of the test and control buildings.

Cost data was also maintained for both PM work and all other repair work. Pretest failures were obtained from an ex post facto examination of maintenance records for the period from November 26, 1984, to February 26, 1985. This time period was used because it corresponded to the test period, and operating demands on the equipment were similar. Failure rates were calculated as the percentage of equipment included in the program which failed, compared to the total amount of equipment included in the program.

Materials and Instruments

Maintenance records of the SASD department of buildings and grounds were used to determine pretest failure rates, estimates of avoidable failures and manpower and material costs for equipment repairs. These records were kept in disk files on an Apple IIe computer running PFS:file and in a conventional file containing original work orders.[5] A computer generated summary of all repairs completed during the period from July 1, 1984, through June 30, 1985, was used to determine which repairs were relevant to the project, and pertinent work orders were obtained from the conventional file. Because of limitations in the computer software, manpower and cost data were tabulated by hand.

SASD records, particularly building plans, were used to develop an inventory of all fixed mechanical equipment. When necessary, this process was supplemented by field investigations. The inventory was tabulated by hand on a form developed for the purpose (Appendix E). Each item of equipment was assigned an inventory number which was affixed to it by tag or paint.

Manufacturers' published service data were obtained for as much equipment as possible. Some of this information was available in departmental files, and some was secured through written requests mailed to the manufacturers.

A master service form was designed, and one was completed for each piece of equipment (Appendix E). A master service file, containing the master service forms and manufacturers' published service data, was established and a calendar file, used for maintenance scheduling, was developed.

Data Collection Methods

An ex post facto examination of the maintenance records of the SASD, covering the period from July 1, 1984, through

June 30, 1985, was conducted to 1) obtain background information on the total number of annual equipment failures, 2) develop an estimate of the number of failures which might have been prevented through PM procedures and 3) develop an estimate of the manpower and material resources which could be devoted to a PM program. The same method was used to determine the number of pretest failures in the test and control groups for the period from November 26, 1984, to February 26, 1985. During the test period, November 25, 1985, to February 25, 1986, numbers of failures were determined by observation, and a continuous record was maintained for each building. Maintenance mechanics recorded their hours and materials directly on the work orders.

Summary Data Analysis Methods

The total number of pieces of fixed mechanical equipment in the test and control groups was determined by a complete inventory or census. Failure rates for both the pretest and test periods were calculated as simple percentages of these totals. The PM program costs were determined by summing the total manhours and material costs devoted to preventive maintenance procedures. More detailed data analysis methods were not deemed necessary since only the gross effects of the PM program were of interest to the researcher.

Limitations of the Project

Definitional

The researcher defined fixed mechanical equipment as any unit permanently mounted or attached to a building and whose function was to perform mechanical work. This included heating, ventilating and air conditioning equipment, electric motors, pumps and air compressors. It did not include components of the building structure, boilers, plumbing fixtures or movable machinery. Whether an item should or should not be included in this definition was the researcher's subjective decision. The implication of this limitation was that the researcher could significantly affect the results through the selection of equipment for inclusion in the PM program.

Methodological

The sample size was limited to eight of the twenty buildings of the SASD. The researcher preferred a larger sample, but given limits on time and manpower, the eight buildings were a practical compromise which allowed successful implementation of the PM program without taxing available resources.

The methodology was also limited by the fact that the sample was not generated randomly. The researcher chose the buildings included in the test and control groups. This allowed a representative selection of building sizes, ages and mechanical complexity, and assured implementation of the PM program in those buildings which, in the researcher's judgement, most needed it. The results, therefore, were not applicable to the District as a whole.

Implementational

The time available for implementation and evaluation of the PM program was a major constraint. This phase occurred during the period from November 25, 1985, to February 26, 1986. Because of seasonal variations in the demands made on various mechanical systems, the effects of the program on some types of equipment, air conditioners, for example, could not be determined.

An additional constraint was the unavailability of manufacturers' service data for some items of equipment. Although the researcher attempted to obtain all such data, some could not be secured. In these cases the researcher or the supervisor of maintenance developed service schedules empirically. Service procedures for the types of equipment involved were, however, essentially standardized, and the effect of this limitation was assumed to be negligible.

A final constraint was the role played by the maintenance department staff in the implementation of the PM program. Eight maintenance mechanics, with differing levels of ability and motivation, were responsible for carrying out the PM tasks. Although the departmental managers attempted to minimize the effects of this variation through close supervision, it was not possible to completely eliminate differences in performance among the personnel involved.

DATA COLLECTION PROCESS	1985					1986			
	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
1. Examine records	*------*								
2. Develop budget		*--*							
3. Develop work standards		*--*							
4. Select equipment		*--*							
5. Develop master form and file		*---*							
6. Inventory equipment			*---*						
7. Obtain service data			*----------*						
8. Develop service schedules			*-----*						
9. Train staff			*-----*						
10. Implement and monitor program				*-------------------------*					
11. Complete comparison of records								*-----*	

Budget

Direct Costs

Printing forms (500 x $.10 per form)	$ 50.00
Postage and office supplies	40.00
Mileage (1,000 miles x $.21 per mile)	210.00
	300.00

Indirect Costs

Repair materials	820.00
Head Custodian (72 hours x $11.50 per hour)	828.00
Maintenance mechanic (180 hours x $12.50 per hour)	2,250.00
Supervisor of maintenance (65 hours x $18.00 per hour)	1,170.00
Clerical time (100 hours x $8.00 per hour)	800.00
Researcher (250 hours x $25.00 per hour)	6,250.00
Subtotal	12,118.00
Total	$12,418.00

Notes

[1] Basil Castaldi, Educational Facilities Planning, Modernization, andManagement, 2d ed. (Boston: Allyn and Bacon, 1982), p. 18.

[2] Sheboygan Area School District, 1985-86 Adopted Budget (Sheboygan, Wi.: Sheboygan Area School District, 1985), pp. 234-250.

[3] Bureau of Economic Statistics, The Handbook of Basic Economic Statistics Monthly Supplement 39, no. 8 (1985):11.

[4] C. William Emory, Business Research Methods, rev. ed. (Homewood, Il.: Richard D. Irwin, 1980), p. 347.

[5] John Page and D.D. Roberts, PFS: file, rev. A (Mountain View, Ca.: Software Publishing, 1983).

CHAPTER 2

Review of the Literature

Introduction

The premature failure rate of certain types of fixed mechanical equipment, such as pumps and air handling units, in the Sheboygan Area School District (SASD) was unacceptably high. This contributed to inflated repair and maintenance costs and limited the ability of district personnel to plan for and control these costs. In addition, planned work schedules of maintenance department employees were frequently interrupted to make emergency repairs on failed equipment. The researcher developed, implemented and evaluated the effect of a preventive maintenance (PM) program on the failure rate of such equipment.

The researcher investigated the factors which have influenced the maintenance needs of public school districts during the last forty years and addressed the issue of how such districts have responded to these maintenance needs. In particular, the effects of a changing society, evolving educational program, and advancing technology on the preventive maintenance (PM) needs of public school districts were examined.

Major Issue #1

What factors have influenced the maintenance needs of public school districts during the last forty years?

The educational system in the United States has changed profoundly since the end of World War II. Directly and indirectly, these changes have affected the maintenance needs of the nation's schools. An understanding of the factors which have influenced these maintenance needs was necessary for the successful development and implementation of a PM program.

Historical Foundation

At the end of World War II the public educational system in the United States had been firmly established and well accepted for more than half a century. The local property tax, supplemented by state appropriations, had been the preferred method of funding since 1870.[1] By 1918, all states had passed compulsory education laws, which, in concert with child labor laws, made universal education a reality.[2] In addition, between 1890 and 1930, the school year had gradually been increased from 135 to 172 days.[3]

During the 1920's and 1930's most larger school districts had adopted an organizational pattern consisting of elementary schools with grades kindergarten through six, junior high schools with grades seven through nine, and senior high schools with grades ten through twelve.[4] Because there had been little new construction between 1940 and 1945, the physical plant in the years immediately following the war was essentially, the same as that of the depression years of the 1930's.[5] This system was severely challenged by the postwar baby boom and the rapidly changing society of the following decades.

As the children of the baby boom grew to school age in the early 1950's, it was apparent that the antiquated facilities of the latter nineteenth and early twentieth centuries were inadequate to meet the needs of the new generation. The most pressing problem was simply the lack of capacity to handle the rising flood of children, and the eventual response was to construct new schools to accommodate them. During the 1950's, annual construction for new educational facilities averaged 2.7 billion dollars.[6] Annual spending increased to 3.7 billion dollars during the 1960's and to 4.95 billion dollars in 1974.[7]

School architecture during the post World War II period tended to be innovative and dramatic. Large expanses of window-walls were built in an effort to bring the outdoors inside.[8] This, however, created problems controlling heat build-up and glare.[9] This was followed in the 1960's, by the era of "finger design", a style which featured a number of long, dead end wings attached to a central core. As educational consultant Basil Castaldi observed, "perimeters were long and energy losses were high. But with a plentiful supply of inexpensive energy, this design posed no significant problems."[10] During the early 1970's, air conditioning systems became a common feature in many new schools.[11]

In general, the net effect of new school construction in the three decades following World War II was to increase the gross maintenance needs of the nation's school systems. Actual maintenance needs, in fact, grew at an even greater rate than the growth of the school systems. During this period there was, according to Joseph J. Baker, Director of Operations with the Mt. Diablo School District, and Jon S. Peters, Professor of Education at Alameda State College,

> a steady movement toward increased mechanization. More and more operations [were] being controlled automatically. The mere fact that operations are

> designed to work automatically does not mean they do not require care. The fact is that the more automatic controls you have, the more technical experience your maintenance personnel will need to keep them working.[12]

The general trend, as technology advanced, was toward larger, more complex schools with far greater maintenance needs than those constructed during the first half of the century. School expansion, however, was often so rapid that maintenance considerations were neglected, and significant losses of capital investments occurred in as little as five to ten years.[13]

The Middle East oil embargo of 1973-1974, probably had a greater affect on alerting school administrators to the need for improved maintenance programs than any other factor before or since. In the decade which followed, per pupil energy costs rose 600 to 750 percent.[14] The higher energy costs resulted in increased taxes and competed with educational programs for funding. Numerous methods of reducing energy consumption were developed and implemented including lowered building temperatures, reduced lighting levels, elimination of decorative and display lighting, and replacement of large expanses of windows with insulating panels.[15] Attention was also focused on improved maintenance and operation of the buildings' mechanical systems. Time clocks and similar control mechanisms were often installed to insure that heating and cooling systems ran only when necessary.[16] States reduced the amount of fresh air required by ventilation codes which permitted the installation of smaller, more efficient systems and allowed oversized systems to be replaced.[17] In 1974, Wisconsin reduced this requirement from 7.5 cubic feet per minute per occupant to 5 cubic feet per minute per occupant.[18] State agencies, such as the Michigan Department of Commerce, developed programs and manuals to aid school administrators in developing maintenance programs which would reduce energy usage.[19] The Wisconsin State Energy Office advocated the development and implementation of preventive maintenance programs "because preventive maintenance will assist in keeping efficiencies high, and also because such a program encourages a consistency indispensible to an energy management program."[20] The Wisconsin Division of State Energy reported that improved operation and maintenance measures "decrease energy consumption by up to 10 percent with minimal financial investment through moderate investment of building staff time."[21] The need to conserve energy to reduce costs, therefore, provided a strong incentive for school districts to improve their maintenance programs. As of 1984 however, less than half of

Wisconsin's 1,954 public schools had taken the necessary actions to improve their energy related maintenance programs.[22]

The maintenance needs of public school districts have shown a steady increase since the end of the Second World War. The baby boom which followed World War II produced rapid growth in the construction of new schools and strained the abilities of the districts to provide effective maintenance. Rapid increases in technology, such as the development of central air conditioning and automatic control systems, also increased the maintenance demands of the nation's public school districts and produced a need for maintenance personnel with greater technical capabilities. The need for improved maintenance programs was forcefully driven home to school administrators by the energy crisis which began in the mid 1970's and has profoundly affected maintenance plans ever since.

Philosophical

Philosophically, school buildings have existed only to meet the physical needs of the educational programs housed within. According to educator John Guy Fowlkes,

> a school building is not only the largest but the most important piece of teaching equipment neces-

> sary for a good school. To be sure a good school building must be safe, and it must provide for an environment that assures the health and well-being of students. But just as important are the nature, adequacy, and arrangement of space in the school building . . . . Just as the tailor fashions the suit to fit the man, so should the school building be fashioned to fit the educational program to be housed.[23]

This philosophy has had two significant implications for the maintenance programs of public school districts. First, it has meant that as education programs have changed and evolved, school buildings, and thus maintenance needs, have changed and evolved with them. Second, it has meant that maintenance programs and considerations have taken a subordinate position with respect to the educational program.

The concept that the school building was the physical expression of the curriculum was a development of the latter part of the twentieth century. According to planning consultant Nickolaus L. Engelhardt,

> during the 19th century and the early part of this century, . . . schools were simply a group of classrooms, usually 8 or 16 in number, corresponding to the grades housed. There were no special facilities of any kind except possibly open areas in the girls' and boys' basements for indoor play. Sometimes two classrooms were separated by a folding partition to provide an assembly space.[24]

The limitations of such school buildings became apparent, however, as the educational program began to include such innovations as kindergartens, manual training, domestic arts, music, dramatics, and gymnastics.[25] Specialized classrooms and instructional areas were developed to accomodate these needs. Schools grew larger and more complex. Science laboratories, gymnasiums, auditoriums, and multipurpose rooms were added which increased the demands on heating, ventilating, and electrical systems. By the 1950's, it was an accepted principle within the educational community, as noted by Stephen J. Knezevich, Dean of the School of Education at the University of Southern California, that the "determination of the educational program precedes designation of the physical pattern and materials of contruction."[26] The implications for the maintenance needs of the schools were clear, whatever the demands of the educational program, the maintenance program would somehow have to adapt.

The philosophy that a school building was an expression of the educational program housed within, led to the concept that to remain functional, a building must adapt to the changing needs of the educational program. According to Knezevich, "a building design that is functional can no more remain static than the educational program it was created to serve."[27] This has meant that as programs have changed, buildings and even individual classrooms have been modified, remodeled, or renovated to accommodate the changes. For example, in the 1960's, team teaching became a common method of instruction. Teachers and students were grouped into different sized class for different purposes, and according to Baker and Peters, "districts adopting it [needed] to remodel existing plants to provide for the size spaces required and the flexibility needed."[28] Even small projects often required the removal or addition of walls, modification of heating and ventilating equipment, and rewiring of electrical systems. Maintenance programs had to constantly adapt and adjust.

Educational consultant Basil Castaldi has stated

> that the design of educational facilities reflects the educational thinking and architectural philosophy at the time when school facilities are proposed, planned, conceived, and constructed. The end product at any given time represents a blending of prevailing architectural concepts, dominant educational practices, and promising curricular innovations. The well-planned educational facility not only provides for the accepted and conventional educational practices that are widespread at the time but also includes features that can accommodate a few of the more promising foreseeable educational concepts of the future.[29]

Beginning with the 1960's and continuing into the early 1970's, many educators and educational architects favored schools without partitions or the open concept as it was known. The philosophy behind this concept was that it promoted greater intermingling of students and teachers and resulted in less regimented education. Problems with discipline and noise, however, led to its fall from favor.[30] Many of the open concept schools have since been subdivided into more traditional classroom areas. Such renovations often required extensive modifications of the original mechanical and electrical systems which were not designed for small spaces.

The failures of the open concept school led to the concept of flexible design. According to this philosophy, schools were planned with long range changes in mind. Walls were temporary structures or partitions which could be easily moved to accomodate unknown future needs, and mechanical and electrical systems were designed to meet the requirements of different configurations of space and equipment.[31] Schools which incorporated these concepts were easily adapted to changing educational programs and were also generally, more easily maintained, assuming equality of construction, than their less flexible, earlier counterparts.

The maintenance needs of the nation's public school districts have thus, philosophically, been a reflection of the educational needs. As educational programs and philosophy have evolved and changed, school buildings, and therefore, indirectly maintenance needs, have changed and evolved to accomodate those needs.

Sociological Foundation

Schools have always been both instruments and products of the society in which they existed. They have been shaped by society and have been charged to carry out specific goals, such as the fostering of patriotism, which were valued by the society of the time. By their very existence, however, schools have also helped shape and change the societies in which they existed. Educational historians Harry G. Good and James T. Teller have reported that in the early years of American independence "Washington and other leaders argued that education should be fostered and employed to overcome sectionalism, to prepare the young for the duties of citizenship in a republic, and to maintain the spirit of liberty."[32] During World War II, schools served the needs of national defense by concentrating on vocational training for defense industries and accelerating the educational pace to get boys into uniform faster.[33]

In the late 1940's and early 1950's, educators saw the essential role of schools as being the preparation of the majority of young adults for adjustment to life in post war society. In 1946, the Office on Education established the Commission on Life Adjustment Education for Youth.[34] According to the commission, 60 percent of American youth were destined for marginal roles in society and should, therefore, be taught how to gain personal satisfaction from life rather than productive job or leadership skills.[35] Reaction against this concept was swift and widespread. Critics, including Mortimer Smith, Bernard Bell, Albert Lynd, Arthur Bestor, Admiral Hyman G. Rickover, and Bryant Conant, emerged calling for stronger academics, greater emphasis on mathematics and science, and a return to basic language and reading skills.[36] Such criticism was often linked with the cold war rhetoric of the 1950's which envisioned the United States falling hopelessly behind the U.S.S.R. The successful launching of the first satellite by the Soviet Union in 1957 seemed to prove the critics were right and led to significant attempts to restructure not only the educational programs of the United States but also the educational system itself. This culminated in 1958, with federal intervention through passage of the National Defense Education Act which provided funds for loans to college students and to strengthen programs in science, mathematics, and foreign languages.[37] The emphasis placed on more rigorous academic programs, particularly in the sciences, led to the expansion of facilities to support such programs. New schools tended to be larger and more complex with more specialty classrooms, and older schools were frequently remodeled in an attempt to accomodate the new needs.

The same period witnessed the breakup of established urban neighborhoods and the growth of the suburbs. Those leaving the cities were mostly middle-class whites while those left behind tended to be less affluent and nonwhite. During the 1950's, the fifty largest American cities all showed increases in the proportion of nonwhite residents.[38] At the same time, suburban population increased by 49 percent while urban areas grew by only 10.6 percent.[39] This left the inner cities with aging, obsolescent, and often poorly maintained schools plus a declining tax base. The suburbs, faced with explosive growth, often could not provide sufficient classroom space and resorted to the use of portable buildings and double teaching shifts.[40] Despite the suburbs' middle-class makeup and the willingness of the residents to fund quality education, the lack of an industrial tax base created significant financial problems. The result was that school contruction was often inadequate to meet the pressing needs and that the schools which were constructed were often of lower quality. Knezevich has reported that

> a building whose inital cost is low is not necessarily an economical building. Indeed, there appears to be an inverse relation between the initial cost of a building and its subsequent maintenance cost. In other words, the lower the initial cost of a building, the greater the likelihood of early and continued high maintenance expenses during the lifetime of the structure."[41]

Thus, the flight to the suburbs resulted in the construction of many facilities with both short and long term maintenance problems.

The criticism of American Education in the 1950's and 1960's coincided with a second major social issue with profound consequences for education, the fight for equal rights for American Blacks. In 1954, the United States Supreme Court, in the case of Brown VS. Kansas, ruled that separate but equal educational facilities for blacks and whites violated basic Constitutional rights and ordered integration with "all deliberate speed."[42] Although desegregation did not occur overnight, it played a significant role in the consolidation of numerous small school districts into fewer large districts.[43] In 1932, when the first national count of school districts was made, there were 127,649 but in 1969, there were only 19,977.[44] Larger districts not only cut across the artificial boundaries which had been established to foster segregation, but also allowed the development of more complete educational programs, increased the tax base, and provided for economies of scale.[45] The general trend was toward larger, more complex districts with larger, more complex schools and consequently, greater maintenance needs.

In the 1960's, the fight for equality and equality of opportunity moved beyond the issue of race to include rights for the mentally and physically handicapped and an end to sexual discrimination.[46] Provisions for equality eventually led to buildings designed with special equipment and facilities which provided barrier free access for the handicapped. In many instances, such provisions were mandated by law. The Wisconsin Administrative Code, which governed building construction in the State of Wisconsin, stated that "access shall be provided to all public-use areas of the building . . . . Interior circulation between floor levels shall be accomplished by the use of ramps, elevators, lifts, or other means of access approved by the department."[47] The sexual equality issue affected schools most strongly in the area of athletic programs for girls and resulted in the provision of expanded facilities such as gymnasiums and girls' team locker rooms. Again, the trend was to larger, more complex schools with greater and more complex maintenance requirements.

The birth rate in the United States peaked in 1961 and then began a slow decline. In 1965 the rate dropped below four million for the first time in a decade, and by the early 1970's, it stabilized at about 3.5 million or approximately the zero population growth level.[48] School districts which had once faced a shortage of classrooms found that they had excess capacity. Responses varied from the closing of obsolescent school buildings to the conversion of extra classrooms to specialty rooms for subjects such as art and music. The net effect reduced the maintenance burden on many districts. In spite of a slight increase in the birth rate, low enrollments continued into the 1980's, but the long term implications were not clear. Robert L. Church, Associate Dean of Education at Northwestern University, speculated that "educators [would] return to some of the custodial interests of the pre-baby boom era as a means of utilizing overbuilt facilities and an abundant supply of teachers."[49]

Sociologically, the demands placed on the nation's public school districts have expanded and grown since the close of World War II. The general tendency has been toward larger, more complex schools and districts with greater and more complex maintenance requirements. A decline in the birth rate through the decade of the 1970's produced some excess capacity in some school districts and allowed the closure of some obsolete facilities. Although this reduced maintenance needs in such instances, the long term implications were not clear.

Legal Foundation

For the most part, certain standards of maintenance have been prescribed by building codes adopted at the state and local level. In Wisconsin, for example, Section 35.93, Chapter 227 of the State Statutes, in 1955, directed publication of the Wisconsin Administrative Code.[50] The stated purpose of the code was

> to protect the health, safety and welfare of the public and employees by establishing minimum standards for the design, construction, structural strength, quality of materials, adequate egress facilities, sanitary facilities, natural lighting, heating, and ventilating, energy conservation, and fire safety for all public buildings and places of employment.[51]

The code specifically required that "all heating, ventilating, exhaust and air conditioning systems shall be maintained in good working order and shall be kept clean and sanitary."[52] Local fire inspectors were charged with code enforcement, and penalties of ten to one hundred dollars were provided for failure to correct each violation.

Most building codes which have been incorporated into local or state statutes were derived from suggested codes of practice published by professional or technical organizations such as the American Society of Mechanical Engineers and the American Standards Association. In 1933, for example, the National Association of Master Plumbers published the Standard Plumbing Code.[53] In 1955 the National Association of Plumbing-Heating-Cooling-Contractors issued standard A40.8 as a model code.[54] This has since been revised at regular intervals. Similarily, the National Electric Code of the National Fire Prevention Association presented model regulations concerned with electrical safety. The National Electric Code was incorporated into the Occupational Safety and Health Act (OSHA) of 1970 and, has since had the force of law.[55] The intent of OSHA was "to assure so far as possible every working man and woman in the nation safe and healthful working conditions and to preserve our human resources."[56] OSHA had many consequences for the maintenance practices of school districts. For instance, Section 1910, Subpart O, addressed guarding provisions for mechanical equipment such as air handling units. Most units installed prior to the act did not have guards over the power transmissions, and OSHA required that such guards be installed and maintained. Similarly, Subpart J addressed general sanitation in the work place and prescribed housekeeping standards. Although OSHA did not directly cover public employers such as school districts, most states adopted the OSHA standards with little change and extended coverage to such employers.

The maintenance activities of most public school districts were, therefore, governed by state and local building codes and by state adopted versions of the Federal Occupational Health and Safety Act. For the most part, these laws required that equipment and buildings be operated and maintained in a safe and sanitary condition. Penalties were provided for failure to comply with such regulations.

Major Issue #2

How have public school districts responded to the maintenance needs of the districts' facilities?

As the educational system in the United States adjusted to meet the ever changing demands of society, the maintenance needs of the nation's schools also changed. An understanding of how public school districts have responded to these changes was an essential requirement for the development and implementation of a successful PM system.

Historical Foundation

The benefits of preventive maintenance programs have been well documented for the last twenty years. Baker and Peters wrote in 1963 "that the most economical maintenance program is in the field of preventative maintenance."[57] Despite this fact, however, preventive maintenance programs have been the exception rather than the rule in public school districts. A study conducted in Michigan during the 1974-1975 school year found that none of the districts had a written policy on preventive maintenance and that only twelve of fifty-nine districts (20.3 percent) had established preventive maintenance programs.[58] According to the author of the study, Paul C. Howell, "public school districts appear to neglect the preventive maintenance function and devote the majority of their maintenance time and money to repairing systems which have failed."[59]

Lack of funding, lack of personnel, and lack of knowledge have been cited as the principle reasons that school districts have failed to implement preventive maintenance programs.[60] Baker and Peters avowed that "despite their importance, maintenance and operations often are treated as administrative stepchildren."[61] Maintenance budgets have frequently been cut so that reductions could be avoided in instructional programs. C. William Day of the School of Education, Indiana University, observed that "educators in this country have had a tendency to wait until major problems . . . occur before attempting to convince the board of education . . . of the need for additional monies. . . ."[62] Lack of personnel, particularly in smaller districts, has also hindered the development of preventive maintenance procedures. Castaldi has noted that "except in very large school districts, the necessary expertise will not be available to create a maintenance prevention plan."[63]

The energy crisis of the 1970's, and the resultant double digit inflation of the early 1980's, led to increased awareness of the need for efficient and economical maintenance programs. It has been demonstrated, for example that timely changing of filters on a typical 20,000 cubic foot per minute air handling unit can save 6,336 kilowatt-hours, or approximately $5,068.80 of electricity annually.[64] In 1979, the United States Department of Energy began funding a state administered Institutional Conservation Program which provided matching grants for energy conservation projects undertaken by school districts.[65] This program emphasized the implementation of improved maintenance and operational procedures to reduce energy consumption. The Michigan Department of Commerce Energy Administration, for example, published a detailed list of preventive maintenance techniques which could reduce energy use in schools.[66]

The increased awareness of the benefits of preventive maintenance resulted in numerous articles being published on the subject in trade journals such as <u>American School and University</u> and <u>Building Operating Management</u>. David R. Howard and Joe N. Mears of the Oakland California School District wrote in 1979 that "preventive maintenance . . . has become a buzz word in school circles" but also noted that "attempts to institute effective programs have been sporatic."[67] John M. Morris, Director of Physical Plant at Monroe Community College, Monroe, Michigan, outlined a step-by-step procedure for developing and implementing a PM program in the August, 1981, issue of American School and University.[68] Most other articles were similar in content and nature and provided practical guidelines for establishing PM programs.

Historically, however, public school districts have not been highly successful in their efforts to implement PM systems despite the recognized merits. The energy shortages of the 1970's increased awareness of the need for and benefits of such programs, but in general, PM systems remained the exception rather than the rule in most school districts.

Psychological Foundation

Psychologically, PM programs have affected both the participants in the programs and the users of the facilities. PM participants often had initial adverse reactions to the programs and resisted their implementation. Michael J. Dwyer, Jr., Director of Campus Operations at the University of Arkansas for Medical Sciences has observed that "many engineers in institutions have avoided implementing a PM program in hopes that the whole idea would go away."[69] This aversion helped to account for Howell's finding that "preventive maintenance is a neglected practice."[70]

Education has played a primary role in overcoming resistance to PM systems. It has been observed that continuing education of maintenance personnel improved awareness of the need for PM and also increased staff expertise.[71] Some maintenance supervisors have advocated assigning the same personnel to the same PM tasks in the belief that this simplified training and increased feelings of pride of ownership.[72] Others have stressed the need for cross-training and warned that important checks may be neglected if allowed to become too routine.[73]

The quality of maintenance has been shown to have a significant impact on the instructional program. David L. Eubanks, Assistant Superintendent of the Spartanburg, South Carolina, School District emphasized that

> It must be recognized that an important relationship exists between a program of instruction and the physical environment in which the program is found. . . . A warm, attractive environment creates a better atmosphere for learning."[74]

Howell stressed that "total preventive maintenance programs are essential to the attainment of the educational goals and objectives of the schools."[75]

An important psychological relationship has also been cited between a district's maintenance staff and the students and faculty. Howard and Mears have indicated the need for the mechanics to "have a high tolerance level for children and the public. . . [and to] be well behaved, cleanly dressed and energetic and knowledgeable about their work."[76] Hypothetically, a professional image fostered more professional work and greater job satisfaction on the part of the employee. In addition, the professional image helped to enhance the students' and faculty's perception of both the employee and the maintenance function.

Psychologically, resistance to PM programs in public school districts was common. Continuing education and the development of more professional maintenance staffs helped to overcome such resistance. In addition, the quality of maintenance in a school district has been linked to the quality of the instructional program. A professional maintenance program has been shown to have a positive impact on students and faculty.

Legal Foundation

Certain legal standards of maintenance have been prescribed by state and local building codes. For example, the Wisconsin Administrative Code required that "all heating, ventilating, exhaust and air conditioning systems shall be maintained in good working order and shall be kept clean and sanitary."[77] PM programs, however, were not mandated, and a great deal of latitude existed regarding both the interpretation and implementation of such requirements.

OSHA, adopted in 1970 by the federal government, sought to assure safe and healthful conditions in the industrial workplace. Although OSHA did not cover public employers such as school districts, most states adopted OSHA-type laws which did. These laws required that mechanical equipment be maintained in safe operating condition. Specific preventive maintenance procedures, however, were not mandated, and the response of school districts to such legal requirements varied greatly. A 1977 study conducted in the state of Michigan, where school maintenance was also governed by the Administrative Rules of Michigan, found that 79.7 percent of the districts surveyed did not have PM programs.[78]

Although legal requirements existed which governed school maintenance, most such laws were rather general in nature and allowed wide discretionary latitude regarding actual implementation. Preventive maintenance systems, for the most part, were not widely adopted.

Economic Foundation

In 1978, California voters passed a constitutional ammendment, Proposition 13, which limited local property taxes and restricted other taxes.[79] This action was widely heralded as the beginning of a taxpayers' revolt, and similar actions followed in other states including New York, Minnesota, Idaho, New Mexico, Rhode Island, Indiana, Maine, Oregon, Washington and Louisiana.[80] In many instances local school districts faced severe revenue reductions due to such tax limiting measures. In California, for example, Proposition 13 resulted in a loss to schools of 3.5 billion dollars or 29.2 percent of total revenues.[81] For many districts, as Morris has observed, this led to "a series of lean budget years, with the physical plant department suffering the greatest cuts."[82] One response to such cuts was to implement or improve PM programs. Dwyer found that "a PM program will. . . lower overall maintenance costs."[83] Similarly, maintenance engineers Robert G. Kozak and John A. Makrias, noted that "significant savings can result from making sure that. . . air conditioning and heating systems are operating efficiently."[84] Morris also observed "that PM allows for the reduction of down time, improved efficiency and prolonged equipment life."[85]

Increased energy costs, the result of the Middle East oil embargo and subsequent energy crisis of the 1970's, also provided strong economic incentives to develop and improve

PM systems. It was reported by the Wisconsin Division of State Energy that improved maintenance and operational procedures can reduce energy consumption by up to 10 percent.[86] Since per pupil energy costs rose by 600 to 750 percent in the decade following the first oil embargo, substantial savings were possible.[87] Kozak and Makrias reported annual energy savings of over $8,600.00 through proper PM of a 500 ton chiller.[88] Frequently, however, the costs and complexities of instituting PM programs have been cited by school districts as justification for failure to implement such programs.[89]

Decreasing budgets coupled with escalating energy costs led some school districts to utilize alternative methods of financing energy conservation projects. Such financing took advantage of federal tax credits which encouraged private investors to fund the projects and then to share part of the savings generated by the reduced energy costs.[90] In most cases, the investors paid for the capital costs of equipment and renovation and then received a percentage of the energy savings for a specified period of time. Such creative financing methods allowed these districts to undertake projects which might have been too costly to fund by conventional means.

In general, PM programs have been a common response by public school districts to increased maintenance and operating costs. The taxpayers' revolt, typified by California's Proposition 13, and increasing energy costs were the greatest economic problems faced by most districts. Occasionally, these problems have led public school districts to seek alternative methods of financing needed capital projects.

Summary

The factors which have influenced the maintenance needs of public school districts during the last forty years were investigated, and the response of such districts to these needs was examined. In general, the maintenance requirements of public school districts have shown a steady increase since the end of World War II. The baby boom following the war produced rapid growth in the construction of new schools and strained the ability of most districts to provide effective maintenance for the new facilities. This problem was compounded by rapid increases in technology, such as the development of central air conditioning systems and automatic control systems, which required greater technical expertise on the part of maintenance personnel. Although the benefits of PM programs were widely known and well documented, public school districts were slow to implement such systems, and as late as 1975, a study conducted in Michigan found that only 20.3 percent of the schools surveyed had instituted PM programs.[91]

The energy crisis of the mid 1970's and the taxpayers' revolt, typified by California's Proposition 13, of the latter 1970's and early 1980's, forced some school districts to adopt PM systems in response to escalating maintenance and operating costs. In addition, the United States Department of Energy encouraged the adoption of improved maintenance practices through the Institutional Conservation Program which provided grants to schools for energy conservation projects. To a great extent, the need to conserve energy as a means of reducing operating costs has had a strong and lasting influence on the maintenance plans of many school districts.

Other factors, including the evolution of the philosophy that the school building was an extension of the educational program and state and federal laws such as OSHA, have also influenced the maintenance practices of public school districts. Although preventive maintenance became something of a "buzz word," attempts to institute PM programs often met with only limited success.[92] For the most part, public school districts have responded slowly to the need for improved maintenance programs, and school maintenance staffs have psychologically resisted the implementation of PM systems.

The general value of PM programs, however, has been demonstrated. They have proven to afford significant cost savings and to play a vital role in the long term attainment of educational goals. The development and implementation of a PM system has been shown to be an essential responsibility of an efficiently managed school maintenance department.

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CHAPTER 3

Findings, Conclusions and Recommendations

Introduction

Purpose of the Project

The premature failure rate of some types of fixed mechanical equipment, such as pumps and air handling units, in the Sheboygan Area School District (SASD) was unacceptably high. This led to inflated maintenance and repair costs and also limited the ability of district personnel to plan for and control these costs. Additionally, planned work schedules of maintenance mechanics were frequently interrupted to make emergency repairs on failed equipment. The researcher developed, implemented and evaluated the effect of a preventive maintenance (PM) program on the failure rate of such equipment.

Research Methology

A quasiexperimental, nonequivalent control group research design was used, in which the control and test groups were chosen for approximate equivalency by the researcher.[1] The control and test groups each consisted of four school buildings selected on the basis of size, age, and mechanical complexity. (See Appendix D for a comparison of the test and control groups.) In this design the independent variable (IV) was preventive maintenance, and the dependent variable (DV) was the failure rate of fixed mechanical equipment.

During the experimental period, November 25, 1985, to February 25, 1986, PM procedures were applied to the fixed mechanical equipment in four buildings. These were South High School, Urban Middle School and Madison and Washington Elementary Schools. Four other buildings, North High School, Farnsworth Middle School and Grant and Longfellow Elementary Schools, selected as controls, did not receive any PM. The number of failures of equipment included in the PM program was determined for each of the test and control buildings.

Cost data was also maintained for both PM work and all other repair work. Pretest failures were obtained from an ex post facto examination of maintenance records for the period from November 26, 1984, to February 26, 1985. This time period was used because it corresponded to the test period, and operating demands on the equipment were similar. Failure rates were calculated as the percentage of equipment which failed, compared to the total amount of equipment included in the program.

The researcher recognized at the start of the project that it was not possible to include all of the district's equipment in the PM program. Due to limitations on the available resources in manpower and material, the researcher decided that only equipment critical to the operations of the SASD, such as emergency power generators, or with potentially high replacement or repair costs, such as electric motors exceeding one-horsepower, would be included in the program. The researcher selected equipment which fit into these two categories from complete equipment inventories. Evaluation criteria included actual repair and replacement costs, as determined from an examination of SASD records. (See Appendix C for a complete list of equipment included in the PM Program.)

The time available for implementation and evaluation of the PM program was the major constraint encountered. This phase occurred during the period from November 25, 1985 to February 25, 1986. Because of seasonal variations in the demands made on various mechanical systems, the effects of the program on some types of equipment, air conditioners, for example, was not evaluated. In addition, the three month time period was quite short in relation to the life expectancy of the equipment involved and may have been too short to fully evaluate the long term effects of the PM program.

Description of Findings

Evaluation Instrument Used

Three principle instruments were used, the inventory form, the master service form, and the standard SASD work order (See Appendix E, F, and G). In addition, a calendar file was developed and used for maintenance scheduling.

In practice a separate work order was issued for each piece of equipment which required PM. This required that 144 individual work orders be typed and was judged to be too time consuming for routine PM purposes. It was, therefore, recommended that a special PM work order be developed with a check-off section for routine tasks. This eliminated the need for excessive clerical time.

Statistical Manipulation of Raw Data

The direct costs incurred for implementation of the PM program were 160.5 manhours of labor and $383.79 of material (See Table 1). Most of the material costs were for replacement belts for air handling units. In addition, six units of equipment with pre-existing failures were discovered during the PM implementation. These units were repaired, but the repair costs were not included in the costs of the PM program (see Table 2). Of the units inspected and serviced in the PM program, forty-three, or 30 percent, were found to have minor but potentially serious problems, such as loose bolts or motor mounts, which were corrected during the PM service. There were also six air handling units discovered which had operable but worn bearings. Replacement of these bearings was scheduled for the summer shut-down.

Table 1

Preventive Maintenance Costs

School	PM Manhours	PM Material Costs (Dollars)
South	90.0	$ 71.15
Urban	49.5	226.13
Madison	16.5	75.01
Washington	4.5	11.50
Total	160.5	$ 383.79

The pretest failure rates during the period from November 26, 1984, to February 26, 1985, were 7.6 percent in the test buildings and 12.2 percent in the control buildings (See Table 3). Following implementation of the program, five equipment failures were experienced in both the test and control groups. This was a failure rate of 3.5 percent and 4.3 percent respectively and represented a reduction in the failure rates of 54 percent in the test buildings and 64 percent in the control buildings. Costs of repair materials during the pretest period were $614.92 for the test group and $424.33 for the control group. Following implementation of the PM program, costs were $286.57 and $554.48 respectively. This represented a decrease of 53 percent for the buildings in the test group and an increase of 31 percent for those in the control group.

Table 2

Repair Costs of Pre-existing Failures

School	No. of Failures	Manhours	Material Costs
South	1	8.0	$ 44.42
Urban	2	19.0	141.16
Madison	3	40.0	393.59
Washington	0	0.0	0.00
Total	6	67.0	$579.17

Findings for Evaluation Objective #1

The failure rate of equipment in the test group during the pretest period was 7.6 percent and was 3.5 percent after implementation of the PM program. This was a reduction of the failure rate of 54 percent. The failure rate of equipment in the control group during the pretest period was 12.2 percent and was 4.3 percent following the test period. This was a reduction of the failure rate of 64 percent.

Table 3

Equipment Failure Rates and Repair Costs

Experimental group	Pre-test failure rate (percent)	Post-test failure rate (percent)	Failure Rate change (percent)
Test	7.6	3.5	-54
Control	12.2	4.3	-64
	Pre-test material costs (dollars)	Post-test material costs (dollars)	Material cost change (percent)
Test	614.92	286.57	-53
Control	424.33	554.48	31

Findings for Evaluation Objective #2

During the pretest period, the cost of repair materials in the test buildings was $614.92 and following implementation of the PM program, was $286.57. This was a reduction of 53 percent. In addition, the cost for materials used to carry out the PM program was $383.79.

During the pretest period, the cost for maintenance materials in the control buildings was $424.33 and following the test period was $554.48. This was an increase of 31 percent.

Analyses of Findings/Conclusions

Evaluation Objective #1

The rate of premature failure of fixed mechanical equipment in the Sheboygan Area School District was reduced by 15 percent, as based upon a comparison of maintenance records prior to and following implementation of the preventive maintenance program.

Conclusion

The failure rate of fixed mechanical equipment in the test buildings declined by 54 percent following implementation of the PM program. The failure rate in the control buildings, however, decreased by 64 percent. It was, therefore, not possible to attribute the reduced failure rate in the test group to the effects of the PM program.

Evaluation Objective #2

The cost for maintenance materials in the Sheboygan Area School District was reduced by 20 percent, as based upon a comparison of maintenance costs prior to and following implementation of the Preventive maintenance program.

Conclusion

The cost for repair materials used in the test buildings was reduced by 53 percent as compared to the pretest period. The cost for repair materials used in the control buildings increased by 31 percent. However, when the cost of materials used in the PM program was added to the cost of repair materials used in the test group, the total cost increased by 9 percent. Nevertheless, since the implementation costs were primarily for replacement belts which would last for several years, the results were consistent with the objective.

Summary/Recommendations

Procedural Recommendations

The researcher recommended that a single person be placed in charge of the PM program. Such a step would assure continuity of the program and enhance accountability and coordination. It would also allow the development of greater expertise in PM procedures on the part of the person selected.

Policy Recommendations

Although the quantitative figures regarding the effects of the PM program on the failure rate of fixed mechanical equipment did not clearly show the benefits of such a system, the observations of the researcher and the other program participants tended to support the premise that a PM program was a necessary and valuable part of a well managed school maintenance operation. The fact that 30 percent of the equipment serviced during implementation of the program was found to have potentially serious problems was the strongest indication of this. The researcher, therefore, recommended that the PM program be extended to all of the buildings in the SASD and that it be incorporated with the routine responsibilities of the department of buildings and grounds.

Future Research Recommendations

The three month time period during which the research took place was much too short. The expected life of most of the equipment involved was twenty years or more, and the number of failures of such equipment which could be expected to occur under even the worst of conditions, during such a short time span, was understandably small. A research period of two years or more could be expected to provide a more reliable indication of the actual effects of a PM program.

In addition to a longer research period, a statistical investigation into a correlation between PM procedures and the failure rate of fixed mechanical equipment was recommended. The researcher was interested only in the gross effects of a PM program in the SASD and thus did not seek to establish this relationship. Such an investigation, however, would provide a fruitful area for further study.

Notes

[1]1 C. William Emory, Business Research Methods, rev. ed. (Homewood, Il.: Richard D. Irwin, 1980), p. 347.

Glossary

Air handling unit: A large, electrically powered fan designed to provide ventilation through a series of ducts.

Downtime: The period of time during which equipment is shut off due to breakdown or for repair or maintenance.

Failure: Breakdown of equipment.

Finger design: A building style which featured a number of deadend wings attached to a central core.

Fixed mechanical equipment: Any unit of equipment permanently mounted or attached to a building and the function of which was to perform mechanical work.

Preventive maintenance: Maintenance work performed on a unit of equipment at regular intervals and designed to prevent breakdown or failure of the equipment.

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Appendix A

Typical Failures

No. M 03486 ✓

SHEBOYGAN AREA SCHOOL DISTRICT

REPAIR REQUEST

5-17-85
DATE ISSUED

TO: BUILDINGS & GROUNDS
Department of Business Services

Requested by Albert Haag
Approved
Work Assigned to:
Completed by Dan Z. On 5/22/85
Time Required to Complete Work 3hrs.
Req. Issued P.O. #

Longfellow
SCHOOL

Art Room
LOCATION OF WORK

DESCRIPTION OF WORK

Fan blades have shifted on shaft causing them not to go around.

WORK COPY

TRANSFER OF MATERIALS (Describe repair above)

No. M 03486

From ______ To ______

Deliver on ______ Return on ______

Released by ______ Picked up by ______ Date ______

Returned by ______ Accepted by ______ Date ______

TEAR OFF BOTTOM OF WORK COPY AT PERFORATION & ATTACH TO MATERIAL BEING TRANSFERRED

SHEBOYGAN AREA SCHOOL DISTRICT

No. M 03264 REPAIR REQUEST

2/26/85
DATE ISSUED

Requested by Art Bord

Approved

TO: BUILDINGS & GROUNDS

Department of Business Services

Work Assigned to:

Completed by TA + WW + DZ + RS + PH. On 3-25-85

Time Required to Complete Work 4.5 + 4.5 + 8.0 + 1.0 + 2.0

North
SCHOOL

Req. Issued P.O. # 07383

Girls Pool Locker Rm. UNIT VENT
LOCATION OF WORK

Wis. 07389

Bear. 07775

Harold

DESCRIPTION OF WORK

Please check The motor on the Force Flow heater for the Girls pool Locker room.
Shaft turns Freely, Belt o.k.
Motor just buzzes when you turn it on. We leave it off now.

Thank you.

MOTOR AT CAM

3-7-85 TA 2.0 3-25-85 2.5

WW 2.0 2.5

WORK COPY

No. M 00613

SHEBOYGAN AREA SCHOOL DISTRICT

REPAIR REQUEST

11-20-84
DATE ISSUED

Requested by Dick Schultz

Approved

Work Assigned to: 62

Completed by DANZ On 12/6/84

Time Required to Complete Work 2½ hrs.

Req. Issued ______ P.O. # 06757

TO: BUILDINGS & GROUNDS
Department of Business Services

Sen. Erdman
SCHOOL

1st grade - corridor
LOCATION OF WORK

DESCRIPTION OF WORK

Motor is over-heating.

TRANSFER OF MATERIALS (Describe repair above)

No. M 00613

From ______ To ______

Deliver on ______ Return on ______

Released by ______ Picked up by ______ Date ______

Returned by ______ Accepted by ______ Date ______

TEAR OFF BOTTOM OF WORK COPY AT PERFORATION & ATTACH TO MATERIAL BEING TRANSFERRED

No.M 01057

SHEBOYGAN AREA SCHOOL DISTRICT
REPAIR REQUEST

11/12/84
DATE ISSUED

Requested by Art Bord

Approved

TO: BUILDINGS & GROUNDS
Department of Business Services

Work Assigned to:
Completed by Dan A. On 11-12-84
Time Required to Complete Work 3
Req. Issued ______ P.O. # 03522
$110.54
Honold Ralage

North
SCHOOL

New Wing Fan Room
LOCATION OF WORK

DESCRIPTION OF WORK

B&G Pump (unit) squealing
Please repair.
Thank You.

WORK COPY

TRANSFER OF MATERIALS (Describe repair above)

No. M 01057

From ______ To ______

Deliver on ______ Return on ______

Released by ______ Picked up by ______ Date ______

Returned by ______ Accepted by ______ Date ______

TEAR OFF BOTTOM OF WORK COPY AT PERFORATION & ATTACH TO MATERIAL BEING TRANSFERRED

No. M 00536

SHEBOYGAN AREA SCHOOL DISTRICT
REPAIR REQUEST

10/9/84
DATE ISSUED

Requested by Dennis Wangerin

Approved

Work Assigned to:

Completed by DAN Z. & RON S. On 10/11/84

Time Required to Complete Work 16 hrs & 4 hrs.

Req. Issued ______ P.O. # ______

TO: BUILDINGS & GROUNDS
Department of Business Services

Pigeon River
SCHOOL

Mechanical Equip. Room
LOCATION OF WORK

DESCRIPTION OF WORK

Please repair Air Handling Unit which is making noise.

Thanks

Time from 10/1/84

TRANSFER OF MATERIALS (Describe repair above)

No. M 00536

From ______ To ______

Deliver on ______ Return on ______

Released by ______ Picked up by ______ Date ______

Returned by ______ Accepted by ______ Date ______

TEAR OFF BOTTOM OF WORK COPY AT PERFORATION & ATTACH TO MATERIAL BEING TRANSFERRED

No.R 11782

SHEBOYGAN AREA SCHOOL DISTRICT
REPAIR REQUEST

7/5/84
DATE ISSUED

Requested by Dennis Wangerin

Approved

Work Assigned to:

Completed by DAN Z & DAN D. On 7/20/84

Time Required to Complete Work 8 hrs. & 2½ hrs

Req. Issued P.O. #

TO: MAINTENANCE DEPT.
Department of Business Services

Pigeon River
SCHOOL

Fan Room
LOCATION OF WORK

DESCRIPTION OF WORK

Repair compressor, makes loud noise.

PROJECTION BULB AND NEEDLE REQUEST:

Bulb Designation Quantity

Quantity

Needle Designation Quantity

WORK COPY

Appendix B

Agenda and PM Program Outline

Department of Business Services
Buildings and Grounds
SHEBOYGAN AREA SCHOOL DISTRICT
Sheboygan, Wisconsin 53081

Maintenance Department Staff Meeting

Wednesday, November 20, 1985

7:00 a.m.

Agenda

1. Preventive Maintenance Program Implementation

2. Staff Development

3. Miscellaneous

November 20, 1985

Preventive Maintenance Procedures

I. PM Work Orders will be issued according to established service intervals and will be designated as such.

II. Work to be performed will be itemized on the Work Order. Do not skip listed items.

III. All time and material must be recorded on the Work Order.

IV. Any problems which are found that require repair should be reported on an Inspection report from. Report forms will be issued with PM Work Orders.

V. PM Work Orders <u>must</u> be completed and returned as soon as the work has been completed.

Appendix C

List of Equipment in PM Program

MECHANICAL EQUIPMENT INVENTORY

BUILDING SOUTH HIGH
DATE
BY

UNIT	LOCATION	DESCRIPTION / MAKE / MODEL	SIZE/HP
SO-AH-A1	GYM CEILING NORTH	AIR HANDLING / TRANE / TORRIVENT 222-1	7.6
SO-AH-A2	GYM CEILING CENTER	AIR HANDLING / TRANE / TORRIVENT 222-1	5
SO-AH-A3	GYM CEILING SOUTH	AIR HANDLING / TRANE / TORRIVENT 317-1	3
SO-AH-A4	ABOVE POOL CEILING	AIR HANDLING / TRANE / TORRIVENT 212-1	2
SO-AH-A5	ABOVE POOL CEILING	AIR HANDLING / TRANE / TORRIVENT 222-1	3
SO-AH-A6	ABOVE CEILING GIRLS LOCKER RM OFFICE	AIR HANDLING / TRANE / TORRIVENT 210-1	1
SO-AH-A7	ABOVE CEILING BOYS VARISTY LOCKERS	AIR HANDLING / TRANE / TORRIVENT 110-1	1/2
SO-AH-A8	ABOVE CEILING BOYS LOCKER RM. OFFICE	AIR HANDLING / TRANE / TORRIVENT 210-1	1
SO-AH-B1	TUNNEL FAN RM. NORTH WING	AIR HANDLING / TRANE / TORRIVENT 210-1	3/4
SO-AH-B2	TUNNEL FAN RM. NORTH WING	AIR HANDLING / TRANE / TORRIVENT - 2-15 FC CAB.	2
SO-AH-B3	TUNNEL FAN RM. SOUTH WING	AIR HANDLING / TRANE / TORRIVENT 217-1	3
SO-AH-B4	TUNNEL FAN RM. EAST WING	AIR HANDLING / TRANE / TORRIVENT 222-1	5
SO-AH-B5	TUNNEL FAN RM. EAST WING	AIR HANDLING / TRANE / TORRIVENT 212-1	2
SO-AH-B6	TUNNEL FAN RM. NORTH WING	AIR HANDLING / TRANE / TORRIVENT 317-1	5
SO-AH-B7	TUNNEL FAN RM. EAST WING	AIR HANDLING / TRANE / TORRIVENT 215-1	2
SO-AH-B8	TUNNEL FAN RM. SOUTH WING	AIR HANDLING / TRANE / CLIMATE CHANGER L-21	5
SO-AH-C1	FAN RM. ABOVE AUTO + METAL SHOP	AIR HANDLING / TRANE / TORRIVENT 212-1	1/2
SO-AH-C2	FAN RM. ABOVE AUTO + METAL SHOPS	AIR HANDLING / TRANE / TORRIVENT 212-1	3/4
SO-AH-C3	FAN RM. ABOVE WOOD + ELECT. SHOPS	AIR HANDLING / TRANE / TORRIVENT 212-1	1/2
SO-AH-C4	FAN RM. ABOVE WOOD + ELECT. SHOPS	AIR HANDLING / TRANE / TORRIVENT 110-1	1/3
SO-AH-C5	FAN RM. ABOVE GENERAL SHOP	AIR HANDLING / TRANE / CLIMATE CHANGER L-10	2
SO-AH-C6	PENTHOUSE ON ROOF WEST WING	AIR HANDLING / TRANE / CLIMATE CHANGER L-21	5

MECHANICAL EQUIPMENT INVENTORY

BUILDING SOUTH HIGH
DATE
BY

UNIT	LOCATION	DESCRIPTION/MAKE/MODEL	SIZE/HP
SO-AH-01	FAN RM. NEXT TO ORGAN LOFT	AIR HANDLING/TRANE/CLIMATE CHANGER 2-27A	7.5/3.3
SO-AH-02	FAN RM. ABOVE MUSIC RMS	AIR HANDLING/TRANE/CABINET 2-12-FD	1/2
SO-AH-03	FAN RM. ABOVE MUSIC RMS.	AIR HANDLING/TRANE/CABINET 2-12-FCI	3/4
SO-CP-1	TUNNEL FAN RM. SOUTH WING	COMPRESSOR/BRUNNER/30PG	3
SO-CP-2	TUNNEL FAN RM. SOUTH WING	COMPRESSOR/BRUNNER/30PG	3
SO-CP-3	BOILER ROOM	COMPRESSOR/CHAMPION/R-15-67A	5
SO-CP-4	BOILER ROOM	COMPRESSOR/CHAMPION/R-15-77J	5
SO-GN-1	TUNNEL-NORTH END EAST WING	GENERATOR/KOHLER/35R88H	92
SO-HX-A1	POOL FILTER ROOM	HEAT EXCHANGER/B+G/	BTU'S/HR 250,000
SO-HX-B1	TUNNEL FAN RM. EAST WING	HEAT EXCHANGER/B+G/	BTU'S/HR 154,000
SO-PU-A1	POOL FILTER RM.	PUMP-CIRCU./B+G/PD1-121	1/2
SO-PU-A2	POOL FILTER ROOM	PUMP-VACUUM/NASH JENNINGS/MD-574	2
SO-PU-A3	POOL FILTER ROOM	PUMP-VACUUM/NASH JENNINGS/MD-574	2
SO-PU-A4	POOL FILTER ROOM	PUMP-COND./NASH JENNINGS/51-1/4C	1
SO-PU-A5	POOL FILTER ROOM	PUMP-COND/NASH JENNINGS/51-1/4C	1
SO-PU-A6	POOL FILTER ROOM	PUMP-CIRCU./VALLEY PUMP/3L6	15
SO-PU-A7	POOL FILTER ROOM	PUMP-SUMP/ARMSTRONG/3D5240	2
SO-PU-A8	POOL FILTER ROOM	PUMP-SUMP/ARMSTRONG/3D5240	2
SO-PU-A9	POOL FILTER ROOM	PUMP-SUMP/	
SO-PU-B1	TUNNEL FAN RM. EAST WING	PUMP-CIRCU./B+G/PD35-T	1/2
SO-PU-B2	TUNNEL FAN RM. EAST WING	PUMP-VACUUM/NASH JENNINGS/MD-334	1
SO-PU-B3	TUNNEL FAN RM. EAST WING	PUMP-VACUUM/NASH JENNINGS/MD-334	1

MECHANICAL EQUIPMENT INVENTORY

BUILDING SOUTH HIGH
DATE
BY

UNIT	LOCATION	DESCRIPTION / MAKE / MODEL	SIZE/HP
SO-PU-B4	TUNNEL FAN RM. EAST WING	PUMP-COND. / NASH JENNINGS / S1-1/4 C	1/2
SO-PU-B5	TUNNEL FAN RM. EAST WING	PUMP-COND. / NASH JENNINGS / S1-1/4 C	1/2
SO-PU-B6	TUNNEL FAN RM. NORTH WING	PUMP-VACUUM / NASH JENNINGS / MD-332	1/2
SO-PU-B7	TUNNEL FAN RM. NORTH WING	PUMP-VACUUM / NASH JENNINGS / MD-332	1/2
SO-PU-B8	TUNNEL FAN RM. NORTH WING	PUMP-COND. / NASH JENNINGS / S1-1/4 C	1/2
SO-PU-B9	TUNNEL FAN RM. NORTH WING	PUMP-COND. / NASH JENNINGS / S1-1/4 C	1/2
SO-PU-B10	TUNNEL FAN RM. SOUTH WING	PUMP-VACUUM / NASH JENNINGS / MD-574	2
SO-PU-B11	TUNNEL FAN RM. SOUTH WING	PUMP-VACUUM / NASH JENNINGS / MD-574	2
SO-PU-B12	TUNNEL FAN RM. SOUTH WING	PUMP-COND. / NASH JENNINGS / S1-1/4 C	1
SO-PU-B13	TUNNEL FAN RM. SOUTH WING	PUMP-COND. / NASH JENNINGS / S1-1/4 C	1
SO-PU-B14	BOILER ROOM	PUMP-BOILER FEED / SCHAUB / S7A-6	3
SO-PU-B15	BOILER ROOM	PUMP-BOILER FEED / SCHAUB / S7A-6	3
SO-PU-B16	BOILER ROOM	PUMP-BOILER FEED / SCHAUB / S7A-6	3
SO-PU-B17	BOILER ROOM	PUMP-BOILER FEED / AURORA / G4-S-BF	1/2
SO-PU-B18	BOILER ROOM	PUMP-DOM. CIRC. / B+G / PBB2-80H	1/6
SO-PU-B19	BOILER ROOM	PUMP-DOM. CIRC. / B+G / PBB2-80H	1/6
SO-PU-B20	BOILER ROOM	PUMP-SUMP / WEINMANN / GAVS	1
SO-PU-B21	BOILER ROOM	PUMP-SUMP / WEINMANN / GAVS	1
SO-PU-B22	TUNNEL FAN RM. SOUTH WING	PUMP-SUMP /	
SO-PU-B23	TUNNEL FAN RM. SOUTH WING	PUMP-SUMP /	
SO-PU-B24	TUNNEL FAN RM. EAST WING	PUMP-SUMP /	
SO-PU-B25	TUNNEL-NORTH END EAST WING	PUMP-SUMP /	

MECHANICAL EQUIPMENT INVENTORY

BUILDING SOUTH HIGH
DATE
BY

UNIT	LOCATION	DESCRIPTION / MAKE / MODEL	SIZE/HP
SO-PU-B26	TUNNEL FAN RM. NORTH WING	PUMP - SUMP/	
SO-PU-B27	TUNNEL FAN RM. EAST WING	PUMP- SUMP/	
SO-PU-B28	TUNNEL FAN RM. NORTH WING	PUMP - SUMP/	
SO-PU-D1	TUNNEL EQUIP RM. UNDE STAGE	PUMP- VACUUM / NASH JENNINGS / MD-334	1
SO-PU-D2	EQUIP. RM. UNDER STAGE	PUMP- VACUUM / NASH JENNINGS / MD - 334	1
SO-PU-D3	EQUIP. RM. UNDER STAGE	PUMP- COND. / NASH JENNINGS / S1 - ¼ C	3/4
SO-PU-D4	EQUIP. RM. UNDER STAGE	PUMP - COND. / NASH JENNINGS / S1 - ¼ C	3/4
SO- PU-D5	EQUIP. RM. UNDER STAGE	PUMP- SUMP / MARLOW / 20 EV- 3A	1/2
SO - PU-D6	EQUIP. RM. UNDER STAGE	PUMP - SUMP/	
SO-PU- D7	EQUIP. RM. UNDER STAGE	PUMP - SUMP/	
SO-RF-A5	ABOVE POOL CEILING	RETURN FAN / TRANE / CABINET 2-24FC	7.5
SO-RF-C6	PENTHOUSE ON ROOF	RETURN FAN / TRANE / CABINET T-14	3
SO-RF-D1	FAN RM. NEXT TO ORGAN LOFT	RETURN FAN / TRANE / CENTRIFUGAL 21	5

MECHANICAL EQUIPMENT INVENTORY

BUILDING URBAN MIDDLE SCHOOL
DATE
BY

UNIT	LOCATION	DESCRIPTION / MAKE / MODEL	SIZE/HP
UR-AH-1	HALL CEILING NEXT TO MUSIC RMS	AIR HANDLING / AAF / H15LPHVYA CENTRAL STATION	7.5
UR-AH-2	FAN RM. UNDER STAGE	AIR HANDLING / CLARAGE / HV	7.5
UR-AH-3	FAN RM. UNDER GYM	AIR HANDLING / CLARAGE / HV	7.5
UR-AH-4	TUNNEL ACROSS FROM CAFE.	AIR HANDLING / TRANE / CLIMATE CHANGER 1-15	1.5
UR-AH-5	TUNNEL ACROSS FROM CAFE.	AIR HANDLING / TRANE / CLIMATE CHANGER CLD803AVOL	1/2
UR-AH-6	TUNNEL ACROSS FROM CAFE.	AIR HANDLING / TRANE / CLIMATE CHANGER L-3	1
UR-AH-7	TUNNEL ACROSS FROM CAFE.	AIR HANDLING / TRANE / CABINET CB0803A03CAR-020	1/2
UR-CP-1	BOILER ROOM	COMPRESSOR / JOHNSON / A5150-2	1.5
UR-CP-2	BOILER ROOM	COMPRESSOR / JOHNSON / A5150-2	1.5
UR-FA-1	FURNACE ROOM SOUTH	FURNACE / THERMO FLO / 1403 - C11	BTU/HR. 115,000
UR-FA-2	FURNACE ROOM NORTH	FURNACE / THERMO FLO / 1403 - C11	BTU/HR 115,000
UR-PU-1	BOILER ROOM	PUMP - DOM. CIRC. / B+G / 189103	1/6
UR-PU-2	BOILER ROOM	PUMP - DOM. CIRC. / CHICAGO / 49304	1/2
UR-PU-3	BOILER ROOM	PUMP - COND. + VAC. / CHICAGO / B46886	5
UR-PU-4	BOILER ROOM	PUMP - COND. + VAC. / CHICAGO / B46886	5
UR-PU-5	BOILER ROOM	PUMP - BOILER FEED / WEINMAN / 1-1/2K11/2	1.5
UR-PU-6	BOILER ROOM	PUMP - BOILER FEED / WEINMAN / 1-1/2 K11/2	1.5
UR-PU-7	BOILER ROOM	PUMP - SUMP / ARMSTRONG / 5240 - 3D	2.0
UR-PU-8	BOILER ROOM	PUMP - SUMP / ARMSTRONG / 5240 - 3D	2.0
UR-PU-9	BOILER ROOM	PUMP - COND. / CHICAGO / 46887	1/2
UR-PU-10	CAFETERIA STORAGE	PUMP - SUMP /	
UR-PU-11	RIFLE RANGE	PUMP - COND. / WATCHMAN / WCD820	1/3

MECHANICAL EQUIPMENT INVENTORY

BUILDING URBAN MIDDLE SCHOOL
DATE ______
BY ______

UNIT	LOCATION	DESCRIPTION / MAKE / MODEL	SIZE/HP
UR-PU-12	RIFLE RANGE	PUMP - COND. / WATCHMAN / WCD820	1/3
UR-PU-13	TUNNEL BELOW RM. 120	PUMP - SUMP /	
UR-PU-14	FAN RM. UNDER STAGE	PUMP - COND. / CHICAGO / 46887	1/2

MECHANICAL EQUIPMENT INVENTORY

BUILDING MADISON SCHOOL
DATE ____________
BY ____________

UNIT	LOCATION	DESCRIPTION / MAKE / MODEL	SIZE/HP
MA-AC-1	ROOF	AIR CONDITIONER / TRANE / RAVA4006F	
MA-AC-2	ROOF	AIR CONDITIONER / TRANE / RAVA3006MA	
MA-AH-1	FAN RM. NEXT TO BOILER RM.	AIR HANDLING / TRANE / CENTRIFUGAL 21	5
MA-AH-2	FAN RM. NEXT TO BOILER RM.	AIR HANDLING / TRANE / CENTRIFUGAL 21	7.5
MA-AH-3	FAN RM. NEXT TO BOILER RM.	AIR HANDLING / TRANE / CENTRIFUGAL 21	5
MA-AH-4	PENTHOUSE NEW WING	AIR HANDLING / TRANE / CLIMATE CHANGER MZ-21	15
MA-AH-5	PENTHOUSE NEW WING	AIR HANDLING / TRANE / CLIMATE CHANGER MZ-17	10
MA-AH-6	POOL EQUIP. RM. WEST	AIR HANDLING / TRANE / TORRIVENT T-6	1.5
MA-AH-7	POOL EQUIP. RM. EAST	AIR HANDLING / TRANE / TORRIVENT T-3	1/4
MA-CP-1	FAN RM. NEXT TO BOILER RM.	COMPRESSOR / DEVILBISS / JUBO-5044	3
MA-GN-1	BOILER ROOM	GENERATOR / KOHLER / 15R88673030	KW-15
MA-HX-1	BOILER ROOM	HEAT EXCHANGER /	
MA-HX-2	BOILER ROOM	HEAT EXCHANGER / B+G / SU104-41	45 G.P.M.
MA-PU-1	BOILER ROOM	PUMP-VAC.+COND. / NASH JENNINGS / AB8016	1.5
MA-PU-2	BOILER ROOM	PUMP-VAC.+COND. / NASH JENNINGS / AB8016	1.5
MA-PU-3	BOILER ROOM	PUMP-SUMP / CHICAGO / F-3460-Z	3/4
MA-PU-4	BOILER ROOM	PUMP-SUMP / ARMSTRONG / 20-5200	3/4
MA-PU-5	BOILER ROOM	PUMP-CIRCU. / CHICAGO /	1
MA-PU-6	BOILER ROOM	PUMP-CIRCU. / CHICAGO /	1.5
MA-PU-7	BOILER ROOM	PUMP-CIRCU. / ROTH / ISAH379B8F	5
MA-PU-8	BOILER ROOM	PUMP-CIRCU. / B+G / 189103	1/6
MA-PU-9	BOILER ROOM	PUMP-DOM. CIR. / B+G / PB12-3357	1/12

MECHANICAL EQUIPMENT INVENTORY

BUILDING MADISON SCHOOL
DATE
BY

UNIT	LOCATION	DESCRIPTION / MAKE / MODEL	SIZE/HP
MA-PU-10	BOILER ROOM	PUMP-CIRCU./DOMESTIC/612 PUF	1
MA-PU-11	BOILER ROOM	PUMP-BOILER FEED/AURORA/ I4A-BF	1
MA-PU-12	BOILER ROOM	PUMP-BOILER FEED/AURORA/ I4A-BF	1
MA-PU-13	POOL FILTER ROOM	PUMP-DOM. CIR./ B+G/ 118 480	1/4
MA-PU-14	POOL FILTER ROOM	PUMP-DOM. CIR/ B+G/ 118844	1/12
MA-PU-15	POOL FILTER ROOM	PUMP-CIRCU./DOMESTIC/612-PVF	1
MA-PU-16	POOL FILTER ROOM	PUMP-SUMP/	
MA-PU-17	POOL FILTER ROOM	PUMP-SUMP/	
MA-PU-18	POOL FILTER ROOM	PUMP-POOL CIRC./STA-RITE/ PRAA56-12	2.5

MECHANICAL EQUIPMENT INVENTORY

BUILDING WASHINGTON SCHOOL
DATE
BY

UNIT	LOCATION	DESCRIPTION / MAKE / MODEL	SIZE/HP
WA-AH-1	FAN RM. EAST	AIR HANDLING / NATIONAL BLOWER WORKS	10
WA-AH-2	FAN RM. WEST	AIR HANDLING / AMERICAN BLOWER / 8	7.5
WA-CP-1	FAN RM. WEST	COMPRESSOR / JOHNSON / A-3100-2	1
WA-PU-1	BOILER ROOM	PUMP - DOM. CIR. / B+G / PBB 4132-5-5	1/12
WA-PU-2	BOILER ROOM	PUMP - BOILER FEED / AURORA / 14A - BF	1
WA-PU-3	BOILER ROOM	PUMP - SUMP / CHICAGO / 35692	1/4
WA-PU-4	PUMP RM.	PUMP - VAC + COND / NASH JENNINGS / 20401	3
WA-PU-5	KITCHEN	PUMP - COND. / AURORA / 40PS-F64	1/3
WA-PU-6	GIRLS WASHROOM BASEMENT	PUMP - COND. / DOMESTIC / 82-CC	1/3

MECHANICAL EQUIPMENT INVENTORY

BUILDING NORTH HIGH
DATE
BY

UNIT	LOCATION	DESCRIPTION / MAKE / MODEL	SIZE/HP
NO-AC-1	FANROOM - GROUND FLOOR	AIR CONDITIONING / TRANE / SUW-503A	
NO-AC-2	COURT YARD	AIR CONDITIONING / CARRIER / 38AD06 4400	
NO-AC-3	STORAGE RM. GROUND FLOOR	AIR CONDITIONING / TRANE / SCX53CK	
NO-AH-1	GYM A STORAGE RM.	AIR HANDLER / TRANE / TORRIVENT 228-1	3
NO-AH-2	GYM A STORAGE RM.	AIR HANDLER / TRANE / TORRIVENT 210-1	1
NO-AH-3	STORAGE RM. POOL BALCONY	AIR HANDLER / TRANE / TORRIVENT 222-1	3
NO-AH-4	GYM C STORAGE RM.	AIR HANDLER / TRANE / TORRIVENT 210-1	1
NO-AH-5	GYM C STORAGE RM.	AIR HANDLER / TRANE / TORRIVENT 29-1	3/4
NO-AH-6	STORAGE RM. POOL BALCONY	AIR HANDLER / TRANE / CLIMATE CHANGER 35	7.5
NO-AH-7	STORAGE RM. POOL BALCONY	AIR HANDLER / TRANE / TORRIVENT 222-1	3
NO-AH-8	STORAGE RM. POOL BALCONY	AIR HANDLER / TRANE / TORRIVENT 222-1	3
NO-AH-9	STORAGE RM. CUST. 1ST FLOOR	AIR HANDLER / TRANE / TORRIVENT 317-1	3
NO-AH-10	STORAGE RM CUST. 2nd FLOOR	AIR HANDLER / TRANE / TORRIVENT 317-1	3
NO-AH-11	STORAGE RM GROUND FLOOR	AIR HANDLER / TRANE / SC103CK	2
NO-AH-12	FAN RM. GROUND FLOOR	AIR HANDLER / TRANE / CENTRIFUGAL 21	15
NO-AH-13	MUSIC STORAGE CEILING	AIR HANDLER / TRANE / TORRIVENT 212-1	1
NO-AH-14	MUSIC STORAGE CEILING	AIR HANDLER / TRANE / TORRIVENT 29-1	1/2
NO-AH-15	ABOVE AUD.	AIR HANDLER / TRANE / CLIMATE CHANGER 31	5
NO-AH-16	ABOVE AUD.	AIR HANDLER / TRANE / CLIMATE CHANGER 31	5
NO-AH-17	LIBRARY STORAGE RM.	AIR HANDLER / TRANE / CLIMATE CHANGER 12	3
NO-AH-18	PUMP RM - NEW WING	AIR HANDLER / CARRIER / 39CA120-219	10
NO-AH-19	FAN RM. - GROUND FLOOR	AIR HANDLER / TRANE / SUW-503 A	3/4

MECHANICAL EQUIPMENT INVENTORY

BUILDING NORTH HIGH
DATE
BY

UNIT	LOCATION	DESCRIPTION/MAKE/MODEL	SIZE/HP
NO-CP-1	BOILER ROOM	COMPRESSOR/INGERSOLL-RAND/2-242E 3	3
NO-CP-2	BOILER ROOM	COMPRESSOR/INGERSOLL-RAND/2-242E 3	3
NO-CP-3	BOILER ROOM	COMPRESSOR/DEVIBISS/VAG5006	5
NO-CP-4	BOILER ROOM	COMPRESSOR/C+H/20-432	5
NO-GN-1	BOILER ROOM	GENERATOR/KOHLER/55R88	KW-50
NO-HX-1	PUMP RM. GROUND FLOOR	HEAT EXCHANGER/B+G/SU-185-4	
NO-HX-2	BOILER ROOM	HEAT EXCHANGER/B+G/SU-167-2	
NO-HX-3	BOILER ROOM	HEAT EXCHANGER/B+G/SU-165-2	
NO-PU-1	POOL FILTER RM.	PUMP-COND+VAC/DOMESTIC/SVLPI-20-35	3/4
NO-PU-2	POOL FILTER RM.	PUMP-COND+VAC./NASH JENNINGS/MO-334	3
NO-PU-3	POOL FILTER RM.	PUMP-COND+VAC./NASH JENNINGS/MO-334	3
NO-PU-4	POOL FILTER RM.	PUMP-CIRCU./AURORA/79-13129	15
NO-PU-5	POOL FILTER RM.	PUMP-SUMP/AURORA/183045	2
NO-PU-6	POOL FILTER RM.	PUMP-SUMP/ARMSTRONG/5400	3
NO-PU-7	POOL FILTER RM.	PUMP-DOM. CIR./B+G/189103	1/6
NO-PU-8	POOL FILTER RM.	PUMP-DOM. CIR./B+G/16021	1/12
NO-PU-9	POOL FILTER RM.	PUMP-COND./	1/3
NO-PU-10	PUMP RM. GROUND FLOOR	PUMP-CIRC./B+G/186863	1/2
NO-PU-11	PUMP RM. GROUND FLOOR	PUMP-CIRC./B+G/118478	3/4
NO-PU-12	PUMP RM. GROUND FLOOR	PUMP-COND./WEIL/3071	1
NO-PU-13	PUMP RM. GROUND FLOOR	PUMP-COND/WEIL/3071	1
NO-PU-14	PUMP RM. GROUND FLOOR	PUMP-SUMP/	

MECHANICAL EQUIPMENT INVENTORY

BUILDING NORTH HIGH
DATE
BY

UNIT	LOCATION	DESCRIPTION / MAKE / MODEL	SIZE/HP
NO-PU-15	PUMP RM. GROUND FLOOR	PUMP - SUMP /	
NO-PU-16	BOILER ROOM	PUMP - CIRCU. / AURORA / GGU	3
NO-PU-17	BOILER ROOM	PUMP - CIRCU. / AURORA / GGU	3
NO-PU-18	BOILER ROOM	PUMP - CIRCU. / AURORA / GGU	5
NO-PU-19	BOILER ROOM	PUMP - CIRCU. / AURORA / GGU	5
NO-PU-20	BOILER ROOM	PUMP - SUMP /	
NO-PU-21	BOILER ROOM	PUMP - BOILER FEED / AURORA / MS-C54 7555 BF	2
NO-PU-22	BOILER ROOM	PUMP - BOILER FEED / AURORA / MS-C54 7555 BF	2
NO-PU-23	BOILER ROOM	PUMP - COND + VAC / NASH JENNINGS / MD-334	2
NO-PU-24	BOILER ROOM	PUMP - COND + VAC / NASH JENNINGS / MD-334	2
NO-PU-25	BOILER ROOM	PUMP - DOM. CIR. / B+G / 16021	1/12
NO-PU-26	BOILER ROOM	PUMP - DOM. CIRC. / B+G / 189034	1/12
NO-PU-27	BOILER ROOM	PUMP - SUMP / AURORA / 183667	3/4
NO-PU-28	BOILER ROOM	PUMP - SUMP / AURORA / 183667	3/4

MECHANICAL EQUIPMENT INVENTORY

BUILDING FARNSWORTH MIDDLE SCHOOL
DATE ____________
BY ____________

UNIT	LOCATION	DESCRIPTION / MAKE / MODEL	SIZE/HP
FA-AC-1	ROOF - NEW WING	AIR CONDITIONER / AAF / KJAAGAHVEM 5703	35
FA-AC-2	ROOF - NEW WING	AIR COND. / DUNHAM-BUSH / RCU-008-55	25
FA-AH-1	GYM CEILING - BOYS	AIR HANDLER / AMERICAN BLOWER / UNIVERSAL UNIVENT	
FA-AH-2	GYM CEILING - GIRLS	AIR HANDLER / AMERICAN BLOWER / UNIVERSAL UNIVENT	
FA-AH-3	TUNNEL UNDER OFFICE	AIR HANDLER / TRANE / CLIMATE CHANGER L-6	1
FA-AH-4	ABOVE STAGE	AIR HANDLER / AMERICAN BLOWER / 6	3
FA-AH-5	ABOVE STAGE	AIR HANDLER / AAF / H9LPHVEYA CENTRAL STATION	1.5
FA-AH-6	ABOVE STAGE	AIR HANDLER / AMERICAN BLOWER / 6	3
FA-AH-7	ART ROOM 130	AIR HANDLER / AAF / H9LPHVEYA CENTRAL STATION	1.5
FA-AH-8	ART ROOM 128	AIR HANDLER / AAF / H9LPHVEYA CENTRAL STATION	1.5
FA-AH-9	WOODSHOP 126	AIR HANDLER / AAF / H9LPHVEYA CENTRAL STATION	2
FA-AH-10	METALSHOP 127	AIR HANDLER / AAF / H2060H17A CENTRAL STATION	1
FA-AH-11	BOYS LOCKER ROOM	AIR HANDLER / AAF / H6LPHVEYA CENTRAL STATION	1
FA-AH-12	ROOM 118	AIR HANDLER / AAF / H6LPHVEYA CENTRAL STATION	1
FA-AH-13	ROOF - NEW WING	AIR HANDLER / AAF / KJAAGAHVEM5703 MULTI - ZONE	15
FA-CP-1	BOILER ROOM	COMPRESSOR / POWERS / HR2D-12	2
FA-CP-2	BOILER ROOM	COMPRESSOR / POWERS / HR2D-12	2
FA-GN-1	BOILER ROOM	GENERATOR / KOHLER / 30R88	KW-31
FA-PU-1	BOILER ROOM	PUMP - COND. + VAC / NASH JENNINGS / D-20	5
FA-PU-2	BOILER ROOM	PUMP - COND. + VAC / NASH JENNINGS / D-20	5
FA-PU-3	BOILER ROOM	PUMP - BOILER FEED / AURORA / M4-BF	1.5
FA-PU-4	BOILER ROOM	PUMP - BOILER FEED / AURORA / H6T-BF	1.5

MECHANICAL EQUIPMENT INVENTORY

BUILDING FARNSWORTH MIDDLE SCHOOL
DATE ____________
BY ____________

UNIT	LOCATION	DESCRIPTION / MAKE / MODEL	SIZE/HP
FA-PU-5	BOILER ROOM	PUMP - DOM. CIR. / B + G / PAZ - 3351	1/12
FA-PU-6	BOILER ROOM	PUMP - SUMP /	
FA-PU-7	BOILER ROOM	PUMP - SUMP / CHICAGO / B33032	2
FA-PU-8	BOILER ROOM	PUMP - SUMP /	
FA-RF-13	ROOF - NEW WING	RETURN FAN / AAF / KJAAGAH V EM 5703 MULTI ZONE	2

MECHANICAL EQUIPMENT INVENTORY

BUILDING GRANT SCHOOL
DATE
BY

UNIT	LOCATION	DESCRIPTION / MAKE / MODEL	SIZE/HP
GR-AC-1	SOUTHWEST PENTHOUSE	AIR CONDITIONER / TRANE / SUW-1003B	
GR-AH-1	SOUTHWEST PENTHOUSE	AIR HANDLING / TRANE / CLIMATE CHANGER L-50	20
GR-AH-2	NORTHEAST PENTHOUSE	AIR HANDLING / TRANE / CLIMATE CHANGER L-31	7.5
GR-AH-3	NORTHWEST PENTHOUSE	AIR HANDLING / TRANE / CLIMATE CHANGER L-50	20
GR-AH-4	SOUTHWEST PENTHOUSE	AIR HANDLING / TRANE / SUW-1003B	2
GR-AH-5	NORTHEAST PENTHOUSE	AIR HANDLING / AAF / H-9-HVFYA CENTRAL STATION	1.5
GR-AH-6	BOILER ROOM	AIR HANDLING / AAF / H-15-HVFYA CENTRAL STATION	2
GR-CP-1	BOILER ROOM	COMPRESSOR / HONEYWELL / WP210B	1/2
GR-CP-2	BOILER ROOM	COMPRESSOR / HONEYWELL / WP210B	1/2
GR-GN-1	BOILER ROOM	GENERATOR / KOHLER / 45R88	92
GR-PU-1	BOILER ROOM	PUMP - CIRCU. / DOMESTIC /	2
GR-PU-2	BOILER ROOM	PUMP - CIRCU. / DOMESTIC /	2
GR-PU-3	BOILER ROOM	PUMP - CIRCU / DOMESTIC /	1.5
GR-PU-4	BOILER ROOM	PUMP - CIRCU. / DOMESTIC /	1.5
GR-PU-5	BOILER ROOM	PUMP - SUMP /	
GR-PU-6	BOILER ROOM	PUMP - SUMP /	1/2
GR-PU-7	BOILER ROOM	PUMP - DOM. CIR. / B+G / 189103	1/6
GR-PU-8	BOILER ROOM	PUMP - DOM CIR. / B+G / 16021	1/12
GR-RF-1	SOUTHEAST PENTHOUSE	RETURN FAN / AMERICAN STANDARD / TUBULAR CENTRIFUGAL	10
GR-RF-2	NORTHEAST PENTHOUSE	RETURN FAN / AMERICAN STANDARD / TUBULAR CENTRIFUGAL	5
GR-RF-3	NORTHWEST PENTHOUSE	RETURN FAN / AMERICAN STANDARD / TUBULAR CENTRIFUGAL	10
GR-RF-4	SOUTHWEST PENTHOUSE	RETURN FAN / AAF / A9LPHV CENTRAL STATION	1

MECHANICAL EQUIPMENT INVENTORY

BUILDING LONGFELLOW SCHOOL
DATE
BY

UNIT	LOCATION	DESCRIPTION / MAKE / MODEL	SIZE/HP
LO-AH-1	BOILER ROOM AREA	AIR HANDLING/TRANE/CLIMATE L-21 CHANGER	3
LO-AH-2	NORTH STORAGE RM. BASEMENT	AIR HANDLING/TRANE/F.C. MULTIBLADE	10
LO-CP-1	BOILER ROOM AREA	COMPRESSOR/JOHNSON/A-3050-1	1/2
LO-GN-1	STORAGE RM. ACROSS FROM BOILER RM.	GENERATOR/KOHLER/15 RM 82	KW-15
LO-PU-1	BOILER ROOM	PUMP-DOM. LIQ./B+G/PBBG-G	1/12
LO-PU-2	BOILER ROOM	PUMP-COND+VAC/NASH JENNINGS/N-42	2
LO-PU-3	BOILER ROOM	PUMP-SUMP/WEIL/BRC	1
LO-PU-4	BASEMENT HALL ACROSS FROM CAFE.	PUMP-SUMP/	

Appendix D

Building Comparison

Building Comparison

School	Date Constructed	Size (sq. ft.)	No. AHU	No. Pumps	Other
South High*	1960/1969	249,640	25	44	10
North High**	1961/1969	246,984	19	28	11
Urban Middle*	1936/1976	156,856	7	14	4
Farnsworth Middle**	1932/1975	103,354	13	8	6
Madison*	1953/1972	57,250	7	18	6
Grant**	1969	68,662	6	8	8
Washington*	1912/1926	54,893	2	6	1
Longfellow**	1890/1919	52,500	2	4	2

*Test building
**Control building

Appendix E

Inventory Form

MECHANICAL EQUIPMENT INVENTORY

BUILDING ____________________
DATE ____________________
BY ____________________

UNIT	LOCATION	DESCRIPTION / MAKE / MODEL	SIZE/HP

Appendix F

Master Service Form

1. ORIGINAL LOCATION ______________________ 2. TRANSFER TO ______________________

3. TRANSFER TO ______________________ 4. TRANSFER TO ______________________

preventative maintenance file

STEP NO.	YEARLY FREQ.	MONTHLY, QUARTERLY OR ANNUAL MAINTENANCE REQUIRED	MONTH SCHEDULED											
			J	F	M	A	M	J	J	A	S	O	N	D

STEP NO.	WEEKLY FREQ.	DAILY OR WEEKLY MAINTENANCE REQUIRED	DAY SCHEDULED						
			M	T	W	T	F	S	S

Appendix G

Work Order

DIAMOND BUSINESS FORMS
SHEBOYGAN, WI 414-458-5505

SHEBOYGAN AREA SCHOOL DISTRICT

REPAIR REQUEST

No. M 08026

DATE ISSUED ______

Requested by ______

Approved ______

Work Assigned to: ______

Completed by ______ On ______

Time Required to Complete Work ______

Req. Issued ______ P.O. # ______

TO: BUILDINGS & GROUNDS
Department of Business Services

______
SCHOOL

______
LOCATION OF WORK

DESCRIPTION OF WORK

WORK COPY

TRANSFER OF MATERIALS (Describe repair above)

No. M 08026

From ______ To ______

Deliver on ______ Return on ______

Released by ______ Picked up by ______ Date ______

Returned by ______ Accepted by ______ Date ______

TEAR OFF BOTTOM OF WORK COPY AT PERFORATION & ATTACH TO MATERIAL BEING TRANSFERRED